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Aggregate Resources Inventory of
Elma Township
Perth County
Southern Ontario

by Staff of the Engineering and Terrain Geology Section, Ontario Geological Survey

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Contents

Abstract 2
Introduction 3
Part I — Inventory Methods 4
Field and Office Methods 4
Resource Tonnage Calculation Techniques 4
Sand and Gravel Resources 4
Bedrock Resources 4
Units and Definitions 5
Part II — Data Presentation and Interpretation 6
Map 1 Distribution of Sand and Gravel Deposits 6
Deposit Symbol 6
Texture Symbol 6
Map 2 Selected Sand and Gravel Resource Areas 6
Site Specific Criteria 7
Deposit Size 7
Aggregate Quality 7
Location and Setting 8
Regional Considerations 8
Map 3 Bedrock Resources 8
Selection Criteria 8
Selected Resource Areas 9
Part III — Assessment of Aggregate Resources in Elma Township 10
Location and Population 10
Physiography and Surficial Geology 10
Extractive Activity 10
Selected Sand and Gravel Resource Areas 11
Sand and Gravel Resource Areas of Secondary Significance 11
Bedrock Geology 12
Summary 12
References 24
Appendix A — Suggested Additional Reading 25
Appendix B — Glossary 26
Appendix C — Geology of Sand and Gravel Deposits 28
Appendix D — Geology of Bedrock Deposits 30
Appendix E — Aggregate Quality Test Specifications 33

TABLES

1. Total Sand and Gravel Resources, Elma Township 14
2. Sand and Gravel Pits, Elma Township 15
3. Selected Sand and Gravel Resource Areas, Elma Township 17
4. Total Identified Bedrock Resources, Elma Township 18
5. Quarries, Elma Township 19
6. Selected Bedrock Resource Areas, Elma Township 20
7. Summary of Test Hole Data, Elma Township 21
8. Summary of Geophysics Data, Elma Township 22
9. Aggregate Quality Test Data, Elma Township 23

FIGURES

1. Key Map Showing the Location of Elma Township 2
2. Bedrock Geology of Southern Ontario 30

MAPS (back pocket)

1. Distribution of Sand and Gravel Deposits, Elma Township, Scale 1:50 000.
2. Selected Sand and Gravel Resource Areas, Elma Township, Scale 1:50 000.
3. Bedrock Resources, Elma Township, Scale 1:50 000.

Aggregate Resources Inventory of Elma Township Perth County

by Staff[1] of the Engineering and Terrain Geology Section

1. Project Supervisors: Dale W. Scott and I. Szoke; field work and report by D. Tennant; compilation and drafting by Staff of the Aggregate Assessment Office. The Mineral Resources Staff of Wingham District and Southwestern Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

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Abstract

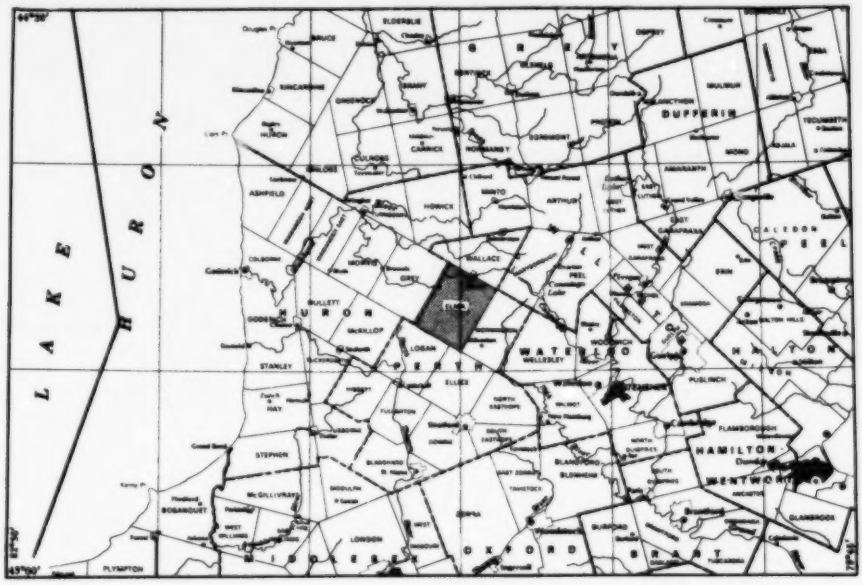


Figure 1. *Key Map Showing the Location of Elma Township, Scale 1:1 800 000.*

This report includes both an inventory and evaluation of sand and gravel, as well as bedrock resources, in Elma Township. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under the Pits and Quarries Control Act.

The deposits in Elma Township contain aggregate of insufficient quality or quantity to warrant primary resource protection. However, several esker, ice-contact and outwash deposits have been selected at the secondary level of significance. These deposits are concentrated in the western half of the township and have a previous history of aggregate extraction.

Dolostone and limestone of the Lucas and Amherstburg Formations of the Detroit River Group underlie a large portion of the township. Scattered areas of 25 to 50 feet (8 to 15 m) of drift cover occur, although most areas in the township are covered by more than 50 feet (15 m) of overburden. Consequently, neither formation is expected to have any current economic value in terms of aggregate production in Elma Township. Dolostone and limestone of the Bois Blanc Formation underlie the northeast corner of the township. This formation is also thickly drift covered.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas where a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1984, the total tonnage of mineral aggregates extracted was 109 million tons (99 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Weatherson 1986).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling, and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites, and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100-pound (11- to 45-kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution, and in some cases Los Angeles abrasion, absorption, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography

maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one-foot (0. 3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (see Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

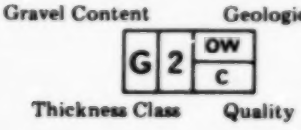
Map 1 is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark red shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light red shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quanitities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1 (greater than 20 feet (6 m) thick), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and Communications (M.T.C.) and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of M.T.C. quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendices B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course A, B and C; Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting

the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalites with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three shades of blue. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas consitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock shown in feet beside it. The test holes may be further described in Table 7.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario

Ministry of Transportation and Communications. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Part III — Assessment of Aggregate Resources in Elma Township

LOCATION AND POPULATION

Elma Township occupies 67,653 acres (27 379 ha) in northern Perth County, southwestern Ontario. Portions of the township appear on the Conestogo (40 P/10), Seaforth (40 P/11) and Wingham (40 P/14) map sheets of the National Topographic System at a scale of 1:50 000.

The total population of Elma Township in 1982 was 3916 (Ontario Ministry of Municipal Affairs and Housing 1985). Agriculture is the primary industry and land use. The land is well suited for agriculture, and a commercial and industrial infrastructure committed to serving agricultural needs has been established. These factors, combined with strong local support for preserving an agricultural lifestyle, has led to the establishment of an "agricultural perspective" in the township's official plan (James F. MacLaren Limited 1978). In keeping with this perspective, population growth is to be discouraged in the rural areas and directed towards the hamlets.

The Town of Listowel (pop. 4968) is the largest urban centre in the area. Listowel is located on the northern boundary of Elma Township and is a major manufacturing and commercial centre. Other locally important centres include Atwood and Monkton and smaller hamlets such as Newry, Donegal, Britton and Trowbridge.

With increases in population, increases in the demand for services and supplies such as aggregate also occur. In Elma, increasing demand and decreasing aggregate supplies have resulted in the formulation of policies to protect the available resources (James F. MacLaren Limited 1978).

The township is accessible by King's Highways 23 and 86, County Roads 6, 8, and 9, and various township roads. Freight service currently runs 3 times a week on a Canadian Pacific Railway line located along the township's southern boundary. A Canadian National Railways line crosses the northeast corner.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Approximately 23 000 years ago, during the Late Wisconsinan Substage of the Pleistocene Epoch (informally known as the "Great Ice Age"), lobes or submasses of the Laurentide continental ice sheet advanced out of the Lake Huron and Georgian Bay lake basins to cover this area. The lateral extent of these ice lobes and the positions of their respective margins underwent numerous fluctuations until approximately 10 000 years ago when the ice finally melted. The physiography and distribution of the surficial materials in Elma Township, and specifically the sand and gravel deposits shown on Maps 1 and 2 of this report, are the result of the oscillations of the Georgian Bay ice lobe during the Port Bruce Stadial of the Pleistocene Epoch.

The Georgian Bay lobe advanced through Elma Township from the north-northeast approximately 14 000 years ago and deposited the Elma Till - a hard, stony, sandy silt till (Cooper et al. 1977). The till is not acceptable as a source of aggregate because of excessive amounts of fine-grained material. During deposition of the Elma Till, several drumlins were formed in northwestern Elma Township. These low drumlins are part of the physiographic region known as the Dundalk Till Plain (Chapman and Putnam 1984). The Dundalk Till Plain is described as a gently undulating, fluted plain characterized by swamps or bogs, and poorly drained depressions.

As the Georgian Bay lobe melted back through the area, several eskers were deposited in Elma Township. These eskers trend northwest-southeast, roughly parallel to the direction of ice movement. The esker located west of Atwood has been the most important source of aggregate in the township in the past and has been extensively excavated. Other smaller eskers are also potential aggregate sources. Several till ridges, marking stages in the retreat of the ice lobe, trend approximately perpendicular to the eskers. The till ridges are unsuitable sources of aggregate.

The drainage of meltwaters from the Georgian Bay lobe resulted in the formation of several outwash and numerous glaciolacustrine deposits. The outwash deposits are small and scattered, but may yield some aggregate of value. A small outwash deposit located along the eastern boundary of the township east of Gotham has yielded a minor amount of granular material (Deike 1982). The glaciolacustrine deposits contain fine sands, silts, and clays (Cooper et al. 1977). These fine-grained glaciolacustrine sediments are not usable as aggregate. However, they were used in the manufacture of drainage tiles at Henfryn (located along the Grey Township - Elma Township boundary) (Guillet 1967). The glaciolacustrine deposits in southeastern Elma make up part of the Stratford Till Plain (Chapman and Putnam 1984). The Stratford Till Plain is described as an area of gently undulating to flat ground moraine which slopes gently to the southwest.

Postglacial erosional and depositional processes have generally been of minor importance in modifying the physiography of the township. Swamps have developed in some areas. In addition, the Dundalk Till Plain has been covered with a shallow deposit of silt, probably windblown, and usually less than 2 feet (0.6 m) thick (Chapman and Putnam 1984).

EXTRACTIVE ACTIVITY

In 1981, Elma Township was designated under the Pits and Quarries Control Act. Prior to that time, a number of pits had been operating on a casual basis throughout the township. Nineteen pits have been identified in this report, and appear on Maps 1 and 2. Most of these pits are now inactive (abandoned) and partially or completely overgrown or rehabilitated. The condition of the pit faces often precluded an assessment of the deposit characteristics. Where possible, data obtained from the Ontario Ministry of Transportation and Communications (M.T.C.) were used to augment information collected during field investigations.

All of the pits shown on Maps 1 and 2 have been rated by M.T.C. as to their ability to supply road-

building and construction aggregate. Only two pits received a "moderate-high" rating, that is, they were capable of producing Granular Base Course (G.B.C.) A and Hot-Laid (H.L.) 4 stone. Nine pits were rated as "moderate sources" and could therefore produce G.B.C. A. Eight pits received "low" ratings and were only capable of supplying road sub-base and G.B.C. B and C (Deike 1982).

At the time of writing there are only two pits licenced for extraction under the Pits and Quarries Control Act. The total area of the pits is 193.0 acres (78.1 ha). Since the year of designation (1981), an average of 133,200 tons (120 839 tonnes) have been extracted from the licenced sources per year.

SELECTED SAND AND GRAVEL RESOURCE AREAS

There are very few deposits in Elma Township which contain sand and gravel. The areal extent of these deposits is only about 2330 acres (940 ha) and the estimated tonnage is 57 million tons (52 million tonnes). Many of the deposits have been extensively worked in the past and there are no resources remaining in Elma suitable for protection at the primary level. However, several esker, outwash and ice-contact deposits have been selected at the secondary level and are capable of producing a variety of granular products. The most important sources of aggregate are the eskers which contain crushable gravel, although the gravel is of poor quality and generally cannot be used to produce high-specification aggregate. Much of the remaining aggregate in the eskers may lie below the water table.

The major problem with the gravels in Elma is that they contain excessive amounts of deleterious materials. The deleterious materials in question are chert and porous limestone. The chert in the area is predominantly derived from the underlying Bois Blanc Formation (Deike 1982). Chert from the Bois Blanc Formation is alkali-silica reactive which means that, in the presence of water, a chemical reaction takes place between the silica in the chert and the alkalies in portland cement paste. The reaction causes a gel to form which expands and causes pressure cracking in the concrete (Deike 1982).

Porous limestones are highly absorptive which wastes expensive asphaltic cement during the paving process. They also have a very low resistance to abrasion which results in rapid wear and loss of surface aggregate when in use (Deike 1982). For these reasons the porous limestones are undesirable components in asphaltic surface course paving (Deike 1982).

The presence of chert and porous limestone was reflected in the results of M.T.C. tests carried out on aggregate samples from Elma Township. The G.B.C. Petrographic Number (P.N.) for representative pits in Elma ranged from 103.6 to 134.5, acceptable for granular base course products (Deike 1982). However, the hot-laid and concrete P.N. was considerably higher, ranging from 223.1 to 345.7 (Deike 1982). These far exceed the specified maximum P.N.s of 140 and 160 for structural concrete and hot-mix asphalt, respectively. The only available Los Angeles Abrasion test result of 28.2 percent loss was well within specification for all products with the exception of H.L. 1 (Deike 1982). Magnesium Sulphate Soundness test results of 11.2 to 15.7 percent loss for coarse aggregate, and 8.5 to 12.9 percent loss for fine aggregate made the tested material unacceptable for most hot-laid stone products but acceptable for most hot-laid sand products. High absorption test results in the range of 3.25 to 4.47 percent again indicated the presence of porous limestone (Deike 1982). These results indicate that the aggregate is generally not suitable for use in any concrete or hot-laid products.

Elma Township currently imports some of the aggregate required for road maintenance from adjacent townships (Ontario Ministry of Natural Resources 1978). As nearby sources are depleted and the cost of transporting aggregate from farther distances increases, the extraction of the material remaining in the secondary areas, particularly below the water table, will become economical. Draglining for similar material in adjacent Logan Township has already begun on a commercial basis. The Elma Township official plan recognizes the need to protect the remaining resources in the township (James F. MacLaren 1978).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

The most important sand and gravel deposit in Elma Township is the Atwood Esker. The Atwood Esker contains several abandoned pits (pit nos. 10 to 12 and 14 to 19). All of these pits are sufficiently overgrown or water filled to mask the characteristics of the esker. Fortunately, M.T.C. data are available for all of the pits and can be used to augment the field data. The face heights in the pits varied from 5 to 20 feet (1.5 to 6 m) and contained 60 to 75 percent gravel. Detailed grading information is not available for all of the pits, however, in pit no. 16, 35 to 60 percent of the gravel fraction was larger than 26.5 mm, and 5 to 15 percent was larger than 102 mm (Deike 1982).

The pits showed some variability in the products which they could produce. Pit no. 10 could only produce select subgrade material (Deike 1982). Pit nos. 11, 12, 17 and 18 could produce select subgrade, G.B.C. A, B and C, and 16 mm Crushed Type B (Deike 1982). Additional M.T.C. data indicate that pit no. 11 contained approximately 10 percent chert and had minor silt and clay coating in places. The field P.N. was estimated to be approximately 115 for granular base course products, and approximately 150 for hot-laid and concrete products. Abandoned pits 14, 16 and 19 could produce hot-laid sand with blending, in addition to G.B.C. A, B and C, and 16 mm Crushed Type B (Deike 1982). The sand fraction tended to be coarse and oversize material had to be removed or crushed in pits 14 and 16 (Deike 1982). In both pits, part of the material was under water. Pit 15 was the only pit in the esker that was capable of producing H.L. 4, 5 and 8 stone in addition to the products previously mentioned (Deike 1982).

Although extensive extraction has already occurred in the Atwood Esker, it may still contain material acceptable for G.B.C. A and pit-run sand and

gravel for local use (Deike 1982). Test holes in pits 12, 14 and 19 show that water is within 8 feet (2 m) of the surface.

A second esker, located southwest of Listowel, contains abandoned pits 4 and 5. According to M.T.C. data, these pits had face heights of 10 to 20 feet (3 to 6 m) and contained 65 to 70 percent gravel (Deike 1982). The coarse granular material was partially below water in pit 5 (Deike 1982). The pits were rated as being capable of producing G.B.C. A, B and C, and 16 mm Crushed Type B (Deike 1982). Testing showed that these pits were contaminated with deleterious material (Deike 1982). Petrographic numbers show that the material in the pits was acceptable for use in granular base course products but unacceptable for hot-laid and concrete products. Absorption test results were 3.25 percent for pit 5. Heavy overburden and the location of aggregate below the waterline may be problems in this deposit.

Two small eskers, located south of Silver Corners along the western boundary of the township and the other located north of Atwood, are probably similar to the Atwood Esker and will probably contain material acceptable for at least pit-run aggregate for local use. A single water well in the esker north of Atwood showed 7 feet (2 m) of overburden overlying 23 feet (7 m) of hardpan gravel.

Four small outwash gravel deposits located southwest of Listowel have also been selected as secondary resources. Although some older maps show that pits have been opened in these deposits, current information is lacking. The deposits were selected according to their expected geological characteristics based on their mode of origin.

The remaining secondary resources are ice-contact stratified drift deposits. Pits 3, 6 and 13 are located within these deposits. These pits had 5- to 15-foot (1.5 to 5 m) faces and contained 10 to 25 percent gravel. They contain mostly sand and are capable of producing G.B.C. B and C (Deike 1982). Pit 3 had a hot-laid and concrete P.N. of 243.8, making it an unacceptable source of hot-laid or concrete products. Water wells in the ice-contact deposits are variable, showing various depths and mixtures of sand, clay and gravel. The deposits may be able to provide some pit-run aggregate for local use.

BEDROCK GEOLOGY

The Lower Devonian Bois Blanc Formation, and the Lower-Middle Devonian Lucas Formation and the Lower Devonian Amherstburg Formation (both of the Detroit River Group) underlie the surficial deposits in Elma Township. The nomenclature history of these formations is complex and the following descriptions are based on the work of Uyeno, Telford and Sanford (1982, pp. 9-15).

The Bois Blanc Formation forms the bedrock of the northeast corner of the township. The formation consists of greenish grey to light grey-brown, medium- to fine-grained, medium- to thin-bedded, cherty, dolomitic limestone with shale partings. It is quarried at Hagersville, Cayuga and Port Colborne for crushed stone. The high chert content of the formation makes much of the material unsuitable for use in concrete aggregate. In Elma Township, the formation is covered by more than 50 feet (15 m) of drift making it uneconomical to quarry for the production of crushed stone.

Most of Elma Township is underlain by bedrock of the Detroit River Group. The Amherstburg Formation overlies the Bois Blanc Formation. In Elma Township, the Amherstburg Formation consists of dark brown, cherty, bituminous dolostone. Only minor portions of the Amherstburg Formation are exposed in quarries in southern Ontario and there is very little available information on its suitability as a source of crushed aggregate. The Amherstburg Formation should be capable of producing products similar to those produced from the Lucas Formation, but extensive testing would be required to establish the quality of the Amherstburg Formation for these purposes. Drift overlying the rock is generally thicker than 50 feet (15 m), although a few small areas of less than 50 feet (15 m) occur. The formation was found to be 143 feet (44 m) thick in an oil and gas well drilled southwest of West Monkton in Logan Township.

The Lucas Formation, the youngest formation in the Detroit River Group, underlies the western third of the township. In some parts of Ontario the formation can be subdivided into undifferentiated Lucas Formation and the Anderdon Member of the Lucas Formation. The Anderdon Member is a very high purity limestone which is quarried near Ingersoll and Amherstburg for use in the production of flux stone, lime and portland cement. Undifferentiated Lucas Formation, which underlies Elma Township, consists of thin- to medium-bedded, light brown to grey-brown, finely crystalline, poorly fossiliferous dolostone with minor chert. Being a dolostone, undifferentiated Lucas Formation is not used in lime and cement production. It is quarried at Amherstburg for crushed stone, and is a borderline to acceptable source of granular base course products and sub-base course products. Problems with excessive fines, and high absorption and soundness losses have been experienced with some of this material (Koniuszy and Katona 1981). Testing would be required to establish the quality of the Lucas Formation in Elma Township.

Drift thickness over the Lucas Formation in Elma Township varies from less than 25 feet (8 m) to over 200 feet (61 m). Two small areas of less than 25 feet (8 m) of drift occur north and west of Atwood. Scattered patches of less than 50 feet (15 m) of drift occur, with the largest one being northwest of Atwood. However, most of the Lucas Formation is overlain by more than 50 feet (15 m) of drift. The log of an oil and gas well drilled southwest of West Monkton in Logan Township encountered 192 feet (58 m) of the formation.

SUMMARY

The sand and gravel resources of Elma Township were deposited during the "Great Ice Age". Although no deposits contain aggregate of sufficient quality or quantity to be designated as primary resources, several esker, ice-contact and outwash deposits have been selected at the secondary level. These deposits, the most important of which are the eskers, are concentrated in the western half of the township and

have a previous history of extraction. The remaining material is acceptable for a variety of granular products, with the exception of high-specification uses. Limiting factors are the presence of chert and porous limestone.

Limestone and dolostone of the Bois Blanc Formation underlie the northeast corner of the Township. Although the formation may be a potential source of crushed stone, it is overlain by more than 50 feet (15 m) of drift. Limestone and dolostone of the Lucas and Amherstburg Formations of the Detroit River Group underlie the remainder of the township. Scattered areas of less than 50 feet (15 m) of drift cover occur over these formations. Neither formation is considered a suitable source of aggregate in Elma Township.

Enquiries regarding the Aggregate Resources Inventory of Elma Township should be directed to the Aggregate Assessment Office, Ontario Geological Survey, Ministry of Northern Development and Mines, Room M1B-45, Macdonald Block, Queen's Park, Toronto, Ontario M7A 1W4 (Tel. (416) 965-1663), or to the Ontario Ministry of Natural Resources either at the Wingham District Office, R.R. 5, Wingham, Ontario, N0G 2W0 (Tel. (519) 357-3131) or at the Southwestern Region Geological Office, 458 Central Avenue, London, Ontario, N6B 2E5 (Tel. (519) 433-8431).

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, ELMA TOWNSHIP*.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
2	G-E	83 (34)	3 (3)
	S-IC	1340 (540)	34 (31)
	S-K	45 (18)	2 (2)
3	G-E	188 (76)	4 (4)
	S-IC-E	59 (24)	1 (1)
	S-IC	180 (73)	4 (4)
	S-K	310 (126)	6 (5)
	G-OW	83 (34)	2 (2)
	S-OW	44 (18)	1 (1)
		2330 (940)	57 (52)

N.B. Minor variations in all tables are caused by rounding of data.

*Deposits within the Town of Listowel have been omitted on all tables.

TABLE 2. SAND AND GRAVEL PITS, ELMA TOWNSHIP.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
LICENCED PITS							
1	C12-003	Donegans Haulage Ltd.	Pt.27, 28	3	57.6 (23.3)	5-10 (1.5-3)	5-20
2	S04-124	Hanna and Hamilton Construction Ltd.	Pt.4.5	7	135.4 (54.8)	-	-
					193.0 (78.1)		
UNLICENCED PITS*							
3	S04-116	Mann	17	1		5-15 (1.5-5)	25 (partially overgrown)
4	S04-119	G.G. Jackson	19	1		10 (3)	65 (pond)
5	C12-047	R. Johnson	11	2		10-20 (3-6)	70 (partially overgrown)
6	S04-027	Gibson	6	3		12 (4)	- (rehabilitated)
7	C12-094	Nichol	15	3		10-20 (3-6)	50
8	C12-079	Whitfield	28	2		7-10 (2-3)	40
9	C12-041	C. Hymer	27,28	2		10-15 (3-5)	20-30 (overgrown)
10	S04-026	Hanna	1	5		10 (3)	- (partially overgrown)
11	S04-074	Hall	1	6		5-10 (1.5-3)	65 (overgrown)
12	S04-132	Hanna and Hamilton	3	6		10-20 (3-6)	- (water filled)
13	S04-006	M. McCourt	6	7		5-15 (1.5-5)	10
14	S04-004	Schyff	7	8		5-7 (1.5-2)	- (overgrown)
15	S04-112	R. Berger	8	8		5-10 (1.5-3)	65-70 (partially overgrown)
16	S04-114	W. McKee	9	8		8-12 (2-4)	60-75 (overgrown)

*Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 2. SAND AND GRAVEL PITS, ELMA TOWNSHIP.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
17	S04-003	Nichols	11,12	9		5-10 (1.5-3)	- (partially overgrown)
18	S04-005	Riddell	14,15	10		5 (1.5)	- (water filled)
19	S04-008	McNeill	13	11		13 (4)	- (overgrown)

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, ELMA TOWNSHIP.

1 **Deposit No.**	2 **Unlicenced Area** Acres (Hectares)	3 **Cultural Setbacks** Acres (Hectares)	4 **Extracted Area** Acres (Hectares)	5 **Available Area** Acres (Hectares)	6 **Estimated Deposit Thickness** Feet (Metres)	7 **Available Aggregate** Millions of Tons (Tonnes)
			- NONE -			

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, ELMA TOWNSHIP.

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
Detroit River Group				
3-25 (1-8)	Lucas Formation	60 (18)	30 (12)	6 (5)
25-50 (8-15)	Lucas Formation	60 (18)	2800 (1130)	600 (540)
			2850 (1150)	610 (550)
25-50 (8-15)	Amherstburg Formation	60 (18)	380 (154)	82 (74)
			3250 (1320)	690 (630)

TABLE 5. QUARRIES, ELMA TOWNSHIP.

1 NO.	2 MTC NO.	3 OWNER/ OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

-NONE-

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, ELMA TOWNSHIP.

1 **DEPOSIT NO.**	2 **DEPTH OF OVERBURDEN** Feet (Metres)	3 **UNLICENCED AREA** Acres (Hectares)	4 **CULTURAL SETBACKS** Acres (Hectares)	5 **EXTRACTED AREA** Acres (Hectares)	6 **AVAILABLE AREA** Acres (Hectares)	7 **ESTIMATED WORKABLE THICKNESS** Feet (Metres)	8 **AVAILABLE RESOURCES** Millions of Tons (Tonnes)

-NONE-

TABLE 7. SUMMARY OF TEST HOLE DATA, ELMA TOWNSHIP.

-NONE-

TABLE 8. SUMMARY OF GEOPHYSICS DATA, ELMA TOWNSHIP

-NONE-

TABLE 9. AGGREGATE QUALITY TEST DATA, ELMA TOWNSHIP.

-NONE-

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging, or application of special crushers (e.g. "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuties. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

Bass Islands Formation (Upper Silurian)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18 m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunnville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate because of high soundness losses.

Bobcaygeon Formation (Middle Ordovician)

Composition: Compact, homogeneous, medium- to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

Bois Blanc Formation (Lower-Middle Devonian)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High cherty content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

Dundee Formation (Middle Devonian)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys as raw material for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

Gull River Formation (Middle Ordovician)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

Lockport and Amabel Formations (Middle Silurian)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone.

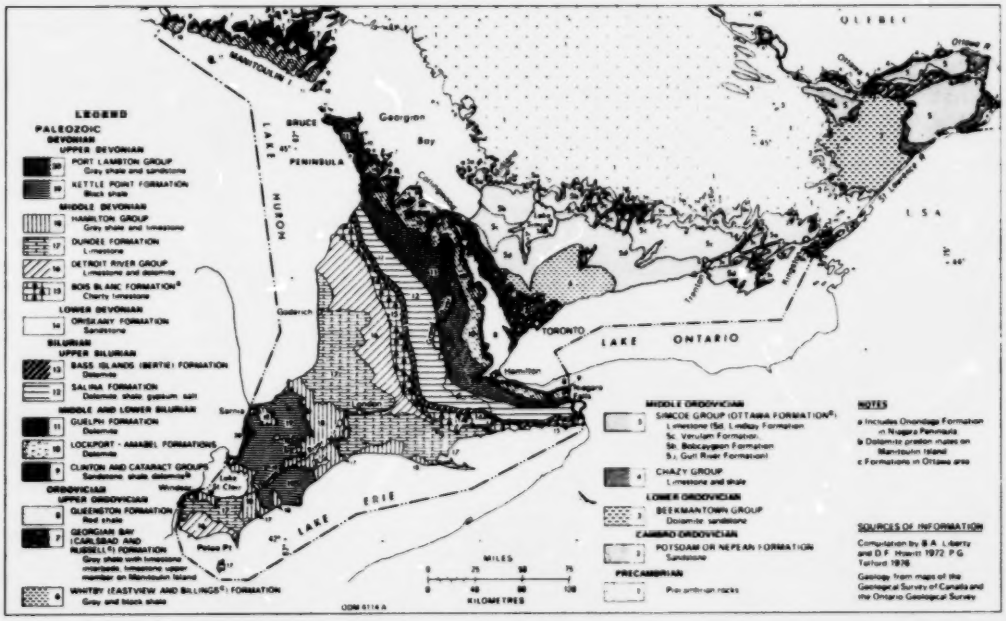

Figure 2. Bedrock Geology of Southern Ontario.

Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

Onondaga Formation (Middle Devonian)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey-brown, fine-grained, very cherty limestone having estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey-brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High cherty content makes much of the material unsuitable for concrete aggregate.

Ottawa Formation (Middle Ordovician)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of limestone for cement production and agricultural uses.

Oxford Formation (Lower Ordovician)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

Detroit River Group (Middle Devonian)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to microcrystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces much of Ontario's lime and cement. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

Grenville Marble (Precambrian)

Composition: Recrystallized fine- to coarse-grained white limestone and dolostone, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

Guelph Formation (Middle Silurian)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. Thickness: 100 to 170 feet (30 to 52 m). Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

Lindsay Formation (Upper Ordovician)

Composition: fine-crystalline, rubbly, nodular-weathering limestone. Collingwood Member: organic-rich interbedded calcareous shales and limestones. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

Verulam Formation (Middle Ordovician)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for use in cement manufacture. The formation is unsuitable for crushed stone because of clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

Georgian Bay Formation (Upper Ordovician)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue-grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in the vicinity of Metro Toronto produce brick and structural tile. Lightweight aggregate has been produced at Streetsville by heat expansion of the shale.

Hamilton Group (Middle Devonian)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona Formation is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). The Arkona Formation has a thickness of 14 to 121 feet (4 to 37 m). Uses: The

Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile.

Queenston Formation (Upper Ordovician)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

Nepean (Potsdam) Formation (Cambro-Ordovician)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

Salina Formation (Upper Silurian)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

Blue Mountain Formation (Upper Ordovician)

(Formerly known as the Whitby Formation) Composition: Blue-grey, predominantly non-calcareous shale. Uses: Quarried at Bowmanville for use in cement production.

Appendix E — Aggregate Quality Test Specifications

Four types of aggregate quality tests are often performed by the Ontario Ministry of Transportation and Communications on sampled material. A description of each test is found in Appendix B while the specification limits for each test are included in this Appendix in Table E1. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this Appendix can be used to determine the suitability of an aggregate. The tests are performed by the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications.

TABLE E-1. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
TYPE OF MATERIAL	Petrographic Number Maximum	Magnesium Sulphate Soundness - Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	-	-	60	-
16 mm Crushed Type 'A'	160	-	-	35	-
16 mm Crushed Type 'B'	200	-	-	60	-
Granular Subbase B	250	-	-	-	-
Granular Subbase C	250	-	-	-	-
Granular Subbase D	-	-	-	-	-
Hot Mix - H. L. 1	100	5	1.0	15	16
Hot Mix - H. L. 2	-	-	-	-	20
Hot Mix - H. L. 3	135	12	1.75	35	16
Hot Mix - H. L. 4	160	12	2.0	35	20
Hot Mix - H. L. 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(M.T.C. Forms 1002, 1003 and 1010)

LEGEND
(continued from right margin)

DEPOSIT SYMBOL

Gravel Content — Geological Type

Thickness Class — Quality Indicator

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e. material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per acre. Geological Type refers to geologic origin. Quality Indicator describes objectionable grain size and lithology.

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.

Thickness Class

Class	Average Thickness in Feet (Metres)	Tons per Acre	Tonnes per Hectare
1	greater than 20 (>6)	greater than 50,000	greater than 112 000
2	10 - 20 (3 - 6)	25,000 - 50,000	56 000 - 112 000
3	5 - 10 (1.5 - 3)	12,500 - 25,000	28 000 - 56 000
4	less than 5 (<1.5)	less than 12,500	less than 28 000

Geological Type

AL	Older Alluvium	**K**	Kame
E	Esker	**LB**	Lacustrine Beach
EM	End Moraine	**LD**	Lacustrine Delta
IC	Undifferentiated Ice-Contact Stratified Drift	**LP**	Lacustrine Plain
		OW	Outwash
ICT	Ice-Contact Terrace	**WD**	Windblown Forms

(see Appendix C for descriptions of Geological Types)

Quality Indicator

	If blank, no known limitations present.
C	Clay and/or silt (fines) present in objectionable quantities.
L	Deleterious lithologies present.
O	Oversize particles or fragments present in objectionable quantities.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Test hole data from Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Northern Development and Mines.
Selected water well data from the Ontario Ministry of the Environment.
Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.
Geology by: A. J. Cooper, W. D. Fitzgerald and J. Clue, 1977.
P. F. Karrow, 1971, 1977.
Additional Fieldwork by: Staff of the Aggregate Assessment Office.
Compilation and Drafting by: Staff of the Aggregate Assessment Office.

This map is to accompany O.G.S. Aggregate Resources Inventory Paper 110.

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Issued 1986.

Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.

LEGEND
(continued from right margin)

DEPOSIT SYMBOL

Gravel Content — Geological Type

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Geological Type

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EM	End Moraine	**LD**	Lacustrine Delta
IC	Undifferentiated Ice-Contact Stratified Drift	**LP**	Lacustrine Plain
		OW	Outwash
ICT	Ice-Contact Terrace	**WD**	Windblown Forms

(see Appendix C for descriptions of Geological Types)

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Issued 1986.

Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.

Ministry of Northern Development and Mines
Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

ELMA TOWNSHIP
PERTH COUNTY

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale 1: 50 000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: 40 P/10, 40 P/11, 40 P/14

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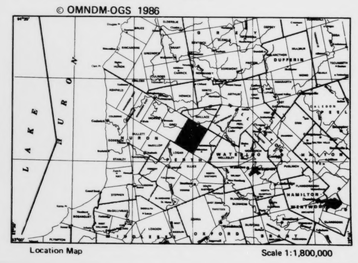

Location Map — Scale 1:1,800,000

LEGEND
(Some map units and symbols may not apply to this map.)

MAP UNITS

- Gravel deposit.
- Sand deposit.
- Gravel overlain by other surficial material.
- Sand overlain by other surficial material.
- Other surficial deposits or exposed bedrock.

SYMBOLS

- Geological and aggregate thickness boundary of sand and gravel deposits.
- Municipal boundary.
- Licenced property boundary; Property number: see Table 2.
- Unlicenced sand or gravel pit*; Property number: see Table 2. *Abandoned pit or wayside pit operating on demand under authority of a permit.
- Test hole location; identification number; see Table 7.
- Selected water well location. Layers of materials are described by: reported thickness of material (in feet); reported type of material (number only - overburden, G - gravel, S - sand, C - clay, T - till, B - boulders, Bk - bedrock).
- Deposit symbol; see below.
- Texture symbol; see below; see Figures
- Geophysical traverse line; Identification number; see Table 8.

TEXTURE SYMBOL

Fines: silt and clay (<.075 mm) — Gravel (>4.75 mm) — Sand (.075 - 4.75 mm)

The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

Location Map — Scale 1:1,800,000

LEGEND
(Some map units and symbols may not apply to this map.)

MAP UNITS

- Gravel deposit.
- Sand deposit.
- Gravel overlain by other surficial material.
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(continued at left margin)

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Ontario

ONTARIO GEOLOGICAL SURVEY

AGGREGATE RESOURCES INVENTORY

ELMA TOWNSHIP

PERTH COUNTY

MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale 1: 50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 40 P/10, 40 P/11, 40 P/14

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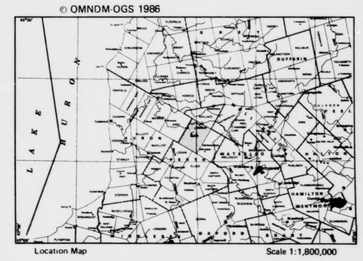

Location Map Scale 1:1,800,000

LEGEND

(Some map units and symbols may not apply to this map.)

MAP UNITS

(1) Selected sand and gravel resource area, primary significance; deposit number; see Table 3.

Selected sand and gravel resource area, secondary significance.

Selected sand and gravel resource area, tertiary significance.

SYMBOLS

Geological and aggregate thickness boundary of sand and gravel deposits.

Municipal boundary

2 Licenced property boundary; Property number: see Table 2.

3 Unlicenced sand or gravel pit*; Property number: see Table 2.
*Abandoned pit or wayside pit operating on demand under authority of a permit.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Geology by: A.J. Cooper, W.D. Fitzgerald and J. Clue, 1977; P.F. Karrow, 1971, 1977

Additional Fieldwork by: Staff of the Aggregate Assessment Office.

Compilation and Drafting by: Staff of the Aggregate Assessment Office,

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Issued 1986.

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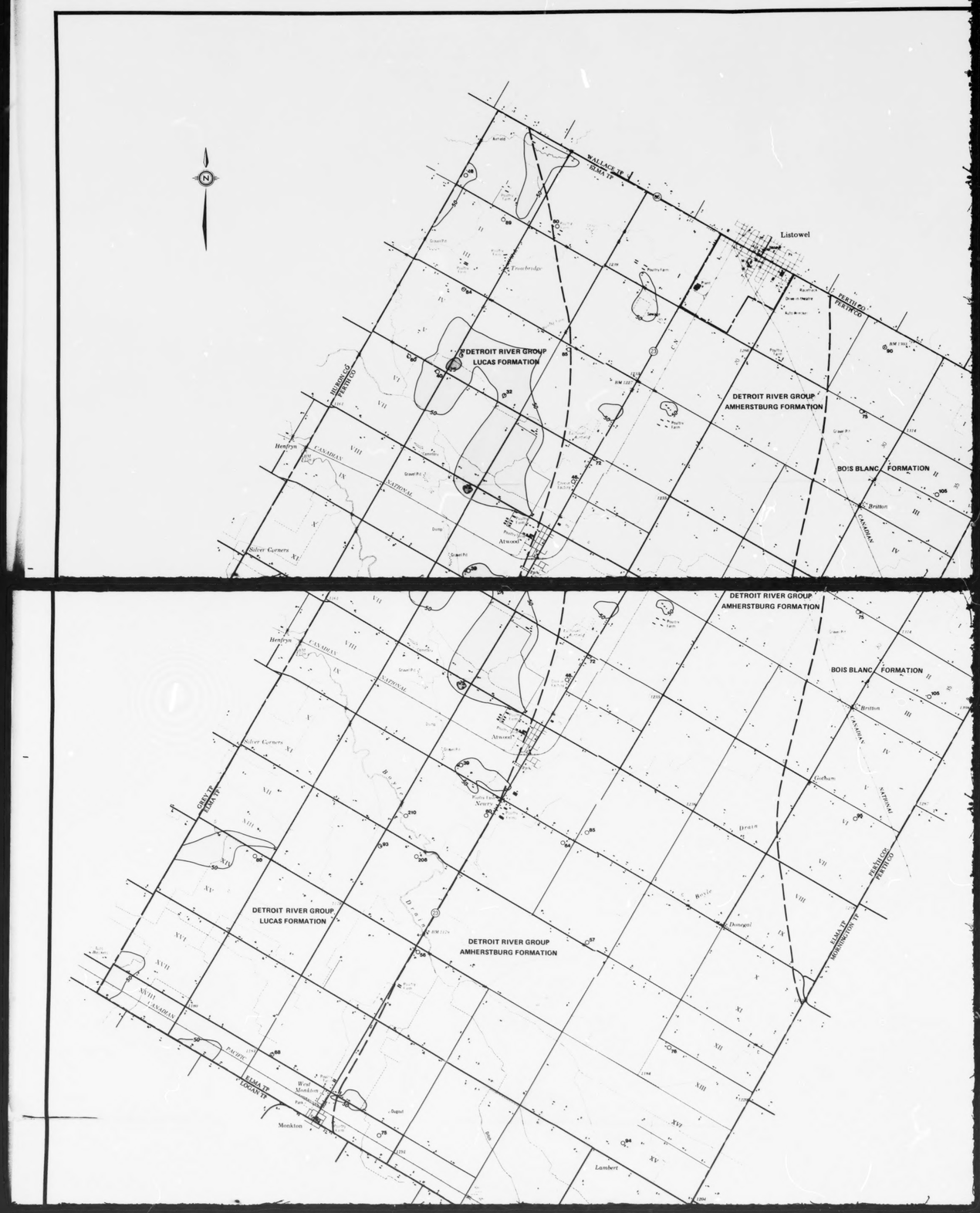

DETROIT RIVER GROUP
AMHERSTBURG FORMATION
BOIS BLANC FORMATION
DETROIT RIVER GROUP
LUCAS FORMATION
DETROIT RIVER GROUP
AMHERSTBURG FORMATION

Ministry of Northern Development and Mines
Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

ELMA TOWNSHIP
PERTH COUNTY

MAP 3
BEDROCK RESOURCES

Scale 1: 50 000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: 40 P/10, 40 P/11, 40 P/14

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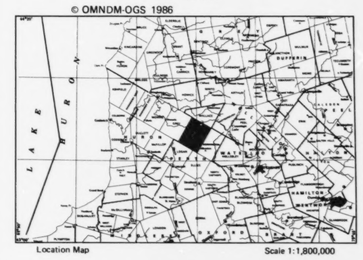

Location Map Scale 1:1,800,000

Location Map Scale 1:1,800,000

LEGEND
(Some units and symbols may not apply to this map.)

BEDROCK UNITS

PALEOZOIC
DEVONIAN
LOWER MIDDLE DEVONIAN
DETROIT RIVER GROUP
LUCAS FORMATION
Dolostone, Limestone
LOWER DEVONIAN
DETROIT RIVER GROUP
AMHERSTBURG FORMATION
Limestone, Dolostone

BOIS BLANC FORMATION
Limestone, Dolostone

DRIFT THICKNESS

- Bedrock outcrop (see Table 4); areas of exposed bedrock partially covered by a thin veneer of drift. Drift thickness is generally less than 3 feet (1 m).
- Bedrock covered by drift (see Table 4); drift thickness is generally 3 to 25 feet (1 to 8 m). Bedrock outcrops may occur.
- Bedrock covered by drift (see Table 4); drift thickness is generally 25 to 50 feet (8 to 15 m). Isolated bedrock outcrops may occur.
- Bedrock covered by drift; drift thickness is generally greater than 50 feet (15 m).

SYMBOLS

- (1) Selected bedrock resource area; deposit number; see Table 6.
- Geological formation boundary.
- Geological formation member boundary.
- Formation thickness boundary (see text).
- 25 Drift thickness contour. (3-foot, 25-foot and 50-foot contours are shown).
- Municipal boundary.
- Q2 Licenced quarry boundary; Property number: see Table 5.
- Q3 Unlicenced quarry*; Property number: see Table 5. *Abandoned quarry or wayside quarry operating on demand under authority of a permit.
- x Isolated bedrock outcrop.
- 24 Selected water well location; reported depth to bedrock (in feet).

BOIS BLANC FORMATION
Limestone, Dolostone

DRIFT THICKNESS

- Bedrock outcrop (see Table 4); areas of exposed bedrock partially covered by a thin veneer of drift. Drift thickness is generally less than 3 feet (1 m).
- Bedrock covered by drift (see Table 4); drift thickness is generally 3 to 25 feet (1 to 8 m). Bedrock outcrops may occur.
- Bedrock covered by drift (see Table 4); drift thickness is generally 25 to 50 feet (8 to 15 m). Isolated bedrock outcrops may occur.
- Bedrock covered by drift; drift thickness is generally greater than 50 feet (15 m).

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- (1) Selected bedrock resource area; deposit number; see Table 6.
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- Geological formation member boundary.
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- Q3 Unlicenced quarry*; Property number: see Table 5. *Abandoned quarry or wayside quarry operating on demand under authority of a permit.
- x Isolated bedrock outcrop.
- 24 Selected water well location; reported depth to bedrock (in feet).

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected water well data from the Ontario Ministry of the Environment.
Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: P.F. Karrow and A.J.Ferguson, 1974; B.A. Liberty and T.E. Bolton, 1971; B.V. Sanford and A.J. Baer, 1981; T.T. Uyeno, P.G. Telford and B.V. Sanford, 1982.

Additional Fieldwork by: Staff of the Aggregate Assessment Office.

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